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(54) HOT WATER PROCESS SEPARATION CELL

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GREAT CANADIAN OIL SANDS LIMITED

(71) Applicants (Country):(74) Agent:(45) Issued on:

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CLAIMS: [Show all claims](#)

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This invention relates to an apparatus for the processing of tar sands. Large deposits of these sands are found as the Athabasca deposits in northern Alberta, Canada. The evaluation portion of these deposits occupies about five and one-half million acres and is buried by zero to 2000 feet of overburden. It has been estimated that these deposits consist of about 600 billion barrels of reserves in place, over 350 billion barrels of recoverable reserves of raw tar sand oil and over 250 billion barrels of upgraded synthetic crude oil. See Page 1 of the K. A. Clark Volume edited by M. A. Carrigy, Research Council of Alberta, October, 1963. The recoverable reserves estimate is just about equal to the world-wide reserves estimate of conventional oil, sixty percent of which is in the Middle East.

The tar sands are primarily composed of a fine quartz sand having a particle size greater than that passing a 325 mesh screen. The quartz sand is impregnated with a viscous bitumen in quantities of from 5 to 21 weight percent of the total composition. More typically the bitumen content is from 8 to 15 percent. This bitumen is quite viscous--6° to 8° API gravity--and contains typically 4.5 percent sulfur and 38 percent aromatics. Its specific gravity at 60°F. ranges typically from about 1.00 to about 1.06.

In addition to the bitumen and quartz sand, the tar sands contain clay and silt in quantities of from 1 to 50 weight percent of the total composition. Silt is normally defined as material which will pass a 325 mesh screen but which is larger than 2 microns. Clay is material smaller than 2 microns including some siliceous material of that size.

Several basic extraction methods have been known for many years for the separation of bitumen from the sands. In the

so-called "cold water" method, the separation is accomplished by mixing the sands with a solvent capable of dissolving the bitumen constituent. The mixture is then introduced into a large volume of water, water with a surface agent added, or a solution of a neutral salt in water. The combined mass is then subjected to a pressure or gravity separation.

In the hot water method, the bituminous sands are jetted with steam and mulled with a minor amount of hot water at temperatures in the range of 140° to 210°F. The resulting pulp
10 is dropped into a stream of circulating hot water and carried to a separation cell maintained at a temperature of about 150° to 200°F. In the separation cell, sand settles to the bottom as tailings and bitumen rises to the top in the form of an oil froth. An aqueous middlings layer containing some mineral and bitumen is formed between these layers. A scavenger step may be conducted on the middlings layer from the primary separation step to recover additional amounts of bitumen therefrom. This step usually comprises aerating the middlings as taught by K. A. Clark, "The Hot Water Washing Method," Canadian Oil and
20 Gas Industries 3, 46 (1950). These froths can be combined, diluted with naphtha and centrifuged to remove more water and residual mineral. The naphtha is then distilled off and the bitumen is coked to a high quality crude suitable for further processing.

The present invention relates to a new separation cell specifically designed for use in the hot water process for treating tar sands. Since the separation of bitumen from tar sands by the hot water process presents problems not encountered in other separation processes, the design of a separation
30 cell for this purpose is necessarily non-analogous to the problems faced in designing for other processes. For example,

in the hot water process it is necessary to provide a quiescent body of water to allow conditioned pulp to separate into its components. The froth which forms at the top of the cell and the sand layer at the bottom of the cell must be removed in such a way as not to disturb this quiescence.

Furthermore it has been found that the separation of the tar sands to form the bitumen froth is dependent upon a delicate maintenance of the density of the middlings of the separation zone. This is achieved by circulating a portion of the aqueous middlings for mixture with bituminous sands before they are discharged into the separation zone. By adjusting the balance between the amount of fresh water and the amount of middlings recycle in the tar sands entering the separation zone, the density of the middlings in the zone can be adjusted. See Canadian Patent 841,581 issued May 12, 1970 to Floyd et al. A suitable separation cell must provide for this middlings recycle for proper operation of the process.

Finally, it is known that a secondary recovery may be obtained from a portion of the aqueous middlings of the separation cell. The separation cell of the present invention uniquely provides for withdrawal of that portion of the middlings most amenable to secondary recovery and thus allows for best utilization of the hot water process for extracting bitumen from tar sands.

Various types of separation zones have been used in the hot water process. Clark used both a pyramid shaped cell with a pump for removing sand tailings and a pipe for removing froth, Canadian Patent 448,321, and also a separation box equipped with a screw conveyor for tailings removal and a wheel for scooping froth from the top of the middlings, Annual Report of the Research Council of Alberta, Rept. 25 (1929), pp. 48-60, (1930).

Another example of a hot water process separation cell is that used by Ball and McClave. The cell is called a quiet zone and comprises a chamber with an inclined bottom, a screw conveyor for conveying sand up through the cell, and a feed conduit, McClave, U. S. Patent 2,130,144, September 13, 1938.

Various other shapes and sizes of cells have been proposed for the separation zone of the process but none of these provides for the froth skimmer and sand rake in combination with a rotatable center shaft which are a part of the cell
10 which is the object of the present invention. Furthermore none of the cells in the art provides for middlings withdrawal for the purpose of recycle to maintain the density of the middlings of the cell.

The cell of this invention comprises a circular tank with a convex bottom and a rotatable center shaft running as a vertical axis to the tank from the tank top toward its bottom. The tank is provided with a middlings outlet. Preferably the tank has two middlings outlets--a lower and an upper outlet. The upper outlet is for removing a stream of relatively oil-
20 rich middlings for secondary recovery by air flotation or other suitable means. The lower outlet is for removing a stream of relatively oil-lean middlings. The oil-lean middlings are recycled and added to tar sands pulp for recharge into the cell. By regulating the rate of the middlings return by means of recycle, while controlling fresh water feed to give the desired feed solids content, the density and viscosity of the cell middlings can be maintained in a certain range according to the invention disclosed in Canadian Patent 841,581 issued May 12, 1970.

30 The tank is provided with an inlet for charging tar sands pulp into the cell and an overflow at the top of the cell for removing bitumen froth. Inside the tank, a froth

skimmer is rotatably connected to the upper portion of the center shaft to be rotated with the shaft. The sand rake is also rotatable with the shaft. The froth skimmer and sand rake respectively serve the functions of skimming bitumen froth to an overflow means connected at the top of the tank, adjacent the lip of the cell, and of moving settled sand to a sand discharge outlet which is located at the lowest portion of the sloping bottom of the cell. Finally the tank is provided with means for rotating the center shaft. This means is usually located at the top of the shaft and comprises conventional drive units. The means is preferably a multiple of drive units for independently rotating the part of the center shaft connected to the froth skimmer and the part connected to the sand rake.

The invention can be described in more detail with reference to the drawings.

Figure 1 of the drawings is a schematic representation of the hot water process in which the separation cell of the present invention is best utilized. Figure 2 is an elevation view, partly in section, of the separation cell and shows the two middlings outlets, the tar sand feed, the tank center shaft, the sand discharge outlet, the overflow means, the froth skimmer and sand rake and the rotating means. Figure 3 is a top view of the cell.

In Figure 1, bituminous tar sands are fed into the system through line 1 where they first pass to a conditioning drum or muller 18. Water and steam are introduced from 2 and mixed with the sands. The total water so introduced is a minor amount based on the weight of the tar sands processed and generally is in the range of 10 to 45 percent by weight of the muller mixture. Enough steam is introduced to raise the

temperature in the conditioning drum to within the range of 130° to 210°F. and preferably to above 170°F. Monovalent alkaline reagent can also be added to the conditioning drum usually in amount of from 0.1 to 3.0 lbs. per ton of tar sand. The amount of such alkaline reagent preferably is regulated to maintain the pH of the middlings layer in separator zone 21 within the range of 7.5-9.0. Best results seem to be obtained at a pH value of 8.0-8.5. The amount of the alkaline reagent that needs to be added to maintain a pH value in the range of 7.5-9.0 may vary from time to time as the composition of the tar sands as obtained from the mine site varies. The best alkaline reagents to use for this purpose are caustic soda, sodium carbonate or sodium silicate, although any of the other monovalent alkaline reagents can be used if desired.

Mulling of the tar sands produces a pulp which then passes from the conditioning drum as indicated by line 3 to a screen indicated at 19. The purpose of screen 19 is to remove from the tar sand pulp any debris, rocks or oversized lumps as indicated generally at 4.

The pulp then passes from screen 19 as indicated by 5 to a sump 20 where it is diluted with additional water from 6 and a middlings recycle stream 7. Recycling of the middlings is not essential in all cases, particularly when the clay content of the tar sands is high. In this event a relatively high rate of fresh feed water introduction through 6 can be employed to compensate for the high clay content while a correspondingly high rate of transfer of middlings layer through line 11 as hereinafter described can be maintained. Under these circumstances recycling of the other stream of middlings through line 7 to the sump is not required.

Modifications that may be made in the process as above described include sending a minor portion of the middlings recycle stream from line 7 through a suitable line (not shown) to the conditioning drum 18 to supply all or a part of the water needed therein other than that supplied through condensation of the steam which is consumed. Also, if desired, a stream of the middlings recycle can be introduced onto the screen 19 to flush the pulp there through and into the sump. As a general rule the total amount of water added to the natural bituminous sands as liquid water and as steam prior to the separation step should be in the range of 0.2-3.0 lbs./lb. of the bituminous sands. The amount of water needed within this range increases as the silt and clay content of the bituminous sand increases. For example, when 15 percent by weight of the mineral matter of the tar sands has a particle size below 44 microns, the fresh water added generally can be about 0.3-0.5 lb./lb. of tar sands. On the other hand, when 30 percent of the mineral matter is below 44 microns diameter, generally 0.7-1.0 lb. of water should be used per pound of tar sands. Correspondingly the amount of oil-rich middlings removed through line 11 will vary depending upon the rate of fresh water addition. As a general rule the rate of withdrawal of oil-rich middlings to scavenger zone 22 will be 10-75 gallons per ton of tar sands processed when 15 percent by weight of the mineral matter is below 44 microns and 150-250 gallons per ton when from 25-30 percent of the mineral is of this fine particle size.

Further following the process, the pulped and diluted tar sands are pumped from the sump 20 through line 8 into the separation zone 21. The separation zone comprises the settling cell of the present invention and will be described more in detail in reference to Figures 2 and 3. The cell contains a

relatively quiescent body of hot water which allows for the formation of a bitumen froth which rises to the cell top and is withdrawn via line 9, and a sand tailings layer which settles to the bottom to be withdrawn through line 10. An aqueous middlings layer between the froth and tailings layer contains silt and clay and some bitumen which failed to form froth. In order to prevent the build up of clay in the system it is necessary to continually remove some of the middlings layer and supply enough water in the conditioning operations to compensate for that so removed. The rate at which the middlings need to be removed from the system depends upon the content of clay and silt present in the tar sands feed and this will vary from time to time as the content of these fines varies. If the clay and silt content is allowed to build up in the system, both the density and the visocisty of the middlings layer will increase. Concurrently with such increase, an increase in the proportions of both the bitumen and the sand retained by the middlings will occur. If the clay and silt content is allowed to build up too high in the system, effective separation no longer will occur and the process will become inoperative. This may be avoided by regulating the recycling and withdrawal of middlings and input of fresh water per the invention disclosed and claimed in Canadian Patent 841,581 issued May 12, 1970 to Floyd etal. However, even when the separation step is operating properly the middlings layer withdrawn through line 11 will contain a substantial amount of bitumen which did not separate. Hence the middlings layer withdrawn through line 11 is, for purpose of description, herein referred to as "oil-rich middlings" or "bitumen-rich middlings."

30 The amount of bitumen remaining in the middlings layer appears to be more or less related to the percentage of clay and/or silt present in the tar sands being processed. varying

directly with the amount of clay and/or silt present. For example, typical oil recovery values for the froth from tar sands in which 15 percent of the mineral matter is less than 44 microns and from sands in which 25-30 percent is less than this size are respectively, 85 percent and 60 percent. For commercial operation it is highly desirable to obtain increased recoveries over such values as these which are obtainable heretofore by the hot water process. This is particularly true when the tar sands as mined contain a relatively high proportion of clay and silt

10 components.

The oil-rich middlings stream withdrawn from separator 21 through line 11 is sent to a scavenger zone 22 wherein an air flotation operation is conducted to cause the formation of additional bitumen froth.

The processing conducted in the scavenger zone involves air flotation by any of the air flotation procedures conventionally utilized in processing of ores. This involves providing a controlled zone of aeration in the flotation cell at a locus where agitation of the middlings is being effected so that air becomes dispersed in the middlings in the form of small bubbles. The drawing illustrates a flotation cell of the sub-aeration type wherein a motorized rotary agitator is provided and air is fed thereto in controlled amount. Alternatively the air can be sucked in through the shaft of the rotor. The rotor effects dispersion of the air in the middlings. This air causes the formation of additional bitumen froth which passes from the scavenger zone 22 through line 12 to a froth settler zone 23. An oil-lean middlings stream is removed and discarded from the bottom of the scavenger zone 22 via line 13.

30 In the settler zone 23, the scavenger froth forms into a lower layer of settler tailings which is withdrawn and recycled

via line 14 to be mixed with oil-rich middlings for feed to the scavenger zone 22 via line 11. In the settler zone an upper layer of upgraded bitumen froth forms above the tailings and is withdrawn through line 14 and mixed with primary froth from line 9 for further processing. The use of gravity settling to upgrade scavenger cell froth is disclosed and claimed in Canadian Patent 857,306 issued December 1, 1970 to Dobson.

The combined froths are at a temperature of about 160°F. They are heated with steam and diluted with sufficient naphtha or 10 other diluent from 16 to reduce the viscosity of the bitumen for centrifuging in zone 24 to produce a bitumen produce 17 suitable for further processing.

Details of the separation cell 21 are shown in Figures 2 and 3. The cell consists of a tank 25 which can be employed in various forms. The tank shown is circular with a convex bottom 26 set on supports 27 and provided with rotatable shafts 28, 29 and 30 arranged concentrically to one another as a vertical axis to the tank 25. The tank is provided with an overflow launder 31 which is positioned at the top of the tank, peripherially around 20 its circumference. This launder 31 is provided for receiving skimmed froth which is then discharged into an overflow outlet 32 for conveying through 9 to the centrifuge zone 24. The froth skimmer comprises a plurality of curved arms 33 with attached blades 34. The skimmer is attached to center shaft 29 which is driven by motor 35 to rotate the skimmer in a horizontal clockwise direction to deflect floating froth toward the launder 31.

The sand rake positioned on center shaft 28 consists of a plurality of arms 36 with connected blades 37 which direct sand to the discharge cone 38 which is connected to the sand tailings 30 discharge line 10 of Figure 1. The cone scraper 39 is an optional feature of the cell and is attached to shaft 30.

Both shafts 28 and 29 are driven by motor 40 but the shafts can be driven separately.

The lifting device and motor 41 provide another alternative feature in the cell and can be used to raise and lower the sand rake 36 to adjust to the level of the sand tailings layer.

The pulp feed conduit 42 is attached to line 8 of Figure 1 and provides for delivering tar sand pulp through the tank 25 to the feed well 43 which is supported by feed well support 47.

The upper middlings conduit 44 is provided at the side of the tank 25 for conveying oil-rich middlings to line 11 of Figure 1 for secondary recovery in scavenger zone 22. The lower middlings conduit 45 is positioned at the side of the tank at a point lower than the upper middlings conduit 44. The lower middlings conduit removes middlings to line 7 for recycle to the sump 20. The recycle is used to maintain the viscosity or density of the middlings contained in the tank 25. Although only one lower middlings conduit 45 and one upper middlings conduit 44 are shown, a plurality of conduits provided around the circumference of the tank can be utilized. 46 is a walk way and hand rail.

Figure 3 is a top view of the cell and shows the separation tank wall 25 with overflow launder 31 and overflow outlet 32. Figure 3 also shows the sand rakes 36 and blades 37, the froth skimmer arms 33, upper middlings outlets 44 and lower middlings outlets 45, shafts 28, 29 and 30 with motors 35 and 40, lifting device and motor 41, and the walk way and hand rails 46, and the feed well support 47.

The following example illustrates, in a general way, a hot water process utilizing the separation cell which is the object of the present invention.

On an hourly basis sufficient amount of the tar sands to give 1000 tons in the feed after screening is fed 1, along with 300 tons of water and steam 2, into a conditioning drum 18. The mixture is heated to about 180°F. while being milled. The resulting pulp is passed through a screen 19 which rejects material of a size $\frac{3}{4}$ " and larger 4. At a sump 20 the screened pulp is mixed continuously with hot water 6 at 190°F. in the amount of 740 tons and with a middlings recycle stream 7 in the amount of 2000 tons. The diluted pulp is then pumped 8 to a separation zone 21 which comprises a single tank with a convex bottom 26 provided with rotatable center shafts 28, 29 and 30 connected to a sand rake 36 at the bottom of the tank and a froth skimmer 33 at the top. The froth skimmer and sand rake rotate at about 0.5 revolutions per minute. In the cell the diluted pulp separates into a bitumen froth which floats to the top of the tank and is skimmed by means of the froth skimmer to a launder 31 and into a sand layer which falls to the bottom of the tank and is raked to a discharge cone 38.

Sand tailings are removed from the cone at the rate of about 800 tons per hour and froth is removed from the launder at a rate of about 40 tons per hour. A bitumen content in the froth corresponding to a recovery of about 60 percent of the bitumen in the original tar sands is obtained. A stream of oil-rich middlings in amount of 1130 tons per hour is withdrawn from the tank through an outlet 44 and transferred 11 to a scavenger zone 22 wherein it is subject to air flotation. Additional oil froth 12 is obtained from the secondary recovery in an amount of 170 tons per hour and about 965 tons per hour of oil-lean

middlings are withdrawn and discarded 13. The secondary froth is settled 23 and added to the primary froth 9 to give a recovery of oil from the tar sands of an over-all value of about 90 percent.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A hot water process separation cell which comprises:

(a) a tank with a convex bottom;

(b) a rotatable center shaft running as vertical axis to said tank from the top of the tank toward the bottom;

(c) a middlings outlet connected to the side of said tank for withdrawing middlings material from said cell;

(d) a tar sands pulp inlet to said tank;

(e) a sand discharge outlet at the bottom of said tank for withdrawing sand tailings layer from said cell;

(f) an overflow means connected at the side of said circular tank and positioned adjacent to said tank to receive bitumen froth;

(g) a froth skimmer, connected to said center shaft, to rotate with said shaft and positioned to direct floating bitumen froth to said overflow means;

(h) a sand rake connected to said center shaft to rotate with said shaft and positioned to move settled sand toward said sand discharge outlet; and

(i) means for rotating said center shaft.

2. The cell of Claim 1 in which (c) comprises a lower middlings outlet connected to the side of said tank for withdrawing middlings material from said cell and an upper middlings outlet above said lower outlet for withdrawing bitumen-rich middlings material from said tank.

3. The cell of Claim 1 in which the froth skimmer and sand rake are connected to rotate at the same rate.

4. The cell of Claim 1 in which the center shaft comprises at least three separate shafts arranged concentrically and separately attached to the froth skimmer and sand rake for separate rotation thereof.

5. The cell of Claim 1 in which the sand discharge outlet comprises a discharge cone.

6. The cell of Claim 5 additionally comprising a cone scraper connected to the bottom of said center shaft and positioned within said discharge cone to rotate with said shaft.

7. The cell of Claim 5 additionally comprising a lifting device positioned at the top of said center shaft attached to said sand rake for raising and lowering the sand rake.

8. The cell of Claim 2 in which the froth skimmer and sand rake are connected to rotate at the same rate.

9. The cell of Claim 2 in which the center shaft comprises at least three separate shafts arranged concentrically and separately attached to the forth skimmer and sand rake for separate rotation thereof.

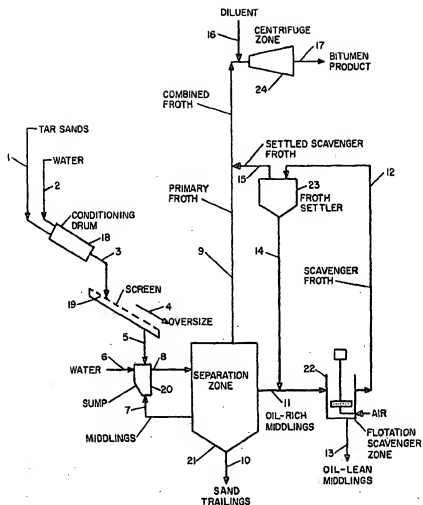
10. The cell of Claim 2 in which the sand discharge outlet comprises a discharge cone.

11. The cell of Claim 10 additionally comprising a cone scraper connected to the bottom of said center shaft and positioned within said discharge cone to rotate with said shaft.

12. The cell of Claim 10 additionally comprising a lifting device positioned at the top of said center shaft attached to said sand rake for raising and lowering the sand rake.



FIGURE 1

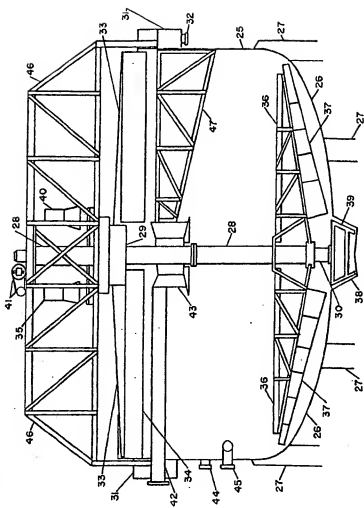


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FIGURE 2



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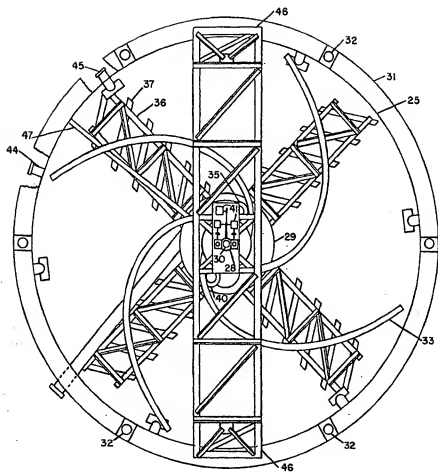
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FIGURE 3



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